

# Water Drainage Model

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**September 27, 1999**

*U.S. Department of Energy*

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## ABBREVIATIONS AND ACRONYMS

2D	two-dimensional
AFC	active fracture concept
AMR	analysis and modeling report
DKM	dual-permeability method
DTN	data tracking number
EBS	engineered barrier system
NBS	natural barrier system
NUFT	nonisothermal unsaturated-saturated flow and transport
QA	quality assurance
TBV	to be verified
TH	thermal-hydrologic
THC	thermal-hydrological-chemical
THM	thermal-hydrological-mechanical
UZ	unsaturated zone
WP	waste package

## **PURPOSE**

The purpose of the water drainage model presented in this AMR is to assess the ability of the EBS to drain water that may enter the EBS.

## **QUALITY ASSURANCE**

This AMR has been developed in accordance with AP-3.10Q, as an implementing document of Work Package 12012383MX and Development Plan TDP-EBS-MD-000013. An activity evaluation, performed in accordance with QAP-2-0 (EBS Performance Modeling, MOL.19990719.0317), determined that this is a quality-affecting document.

The model developed in this AMR will be validated against appropriate experimental data as data becomes available.

Qualified, Unqualified, and Accepted input data and references have been identified, and TBV assigned and documented in Attachment 1 of this report, in accordance with AP-3.15.

Computer Software and Model Usage are discussed in Section 3 of this report. The following unqualified codes are used: NUFT 3.0s, Software Tracking Number is: 10088-3.0s-00. Model results generated using these codes are identified as TBV. Code validation will be addressed as part of the code qualification effort.

In addition to AP-3.10Q, the following procedures are applicable to this document: AP-6.1Q, AP-3.14Q, AP-3.17Q, AP-SI.1Q, AP-SIII.2Q, YAP.SV.1Q

## **COMPUTER SOFTWARE AND MODEL USAGE**

The calculations described in this AMR are performed using the USNT module of NUFT v. 3.0s, run on a SUN Ultra 10 workstation. The Software Tracking Number is: 10088-3.0s-00.

NUFT 3.0s is currently unqualified software due to resource and schedule constraints. Therefore all calculations reported in this AMR must be considered as unqualified (TBV). NUFT 3.0s is in the process of being qualified. The current estimated completion date is 10/1/99. We fully expect that calculation results reported here and the results of future calculations done with the qualified code will be identical.

## **INPUTS**

### **DATA AND PARAMETERS**

#### **NBS**

Table 1 describes a representative column of hydrostratigraphic units at a location at the approximate center of the proposed repository at Yucca Mountain. As of mid-September 1999, this information was not available from the Yucca Mountain technical databases, so all values in Table 1 must be regarded as TBV.

Table 2 gives parameters that described the repository plane with respect to the repository location represented by Table 2. Due to the TBV status of Table 1, this information although based on information from DTN SN9908T0872799.004, must also be considered TBV.

Table 3 lists assumed ground surface temperature and pressure, and water table temperature at the repository location represented by the column in Table 1. Values listed in Table 3 must be regarded at this time as TBV.

Tables 4-7 list hydrologic and thermal properties for the model units listed in Table 1. All these data are from DTN LB997141233129.001. These hydrologic parameters are labeled in this DTN as "1-D only, calibrated flow parameters for a basecase infiltration".

Table 8 lists the infiltration rates that corresponds these parameters. These infiltration rates must be considered TBV.

#### **EBS**

Table 9 and 10 list hydrologic and thermal properties for EBS materials. This information is from Design Input Transmittal PA-SSR-99218.Tb.

Table 11 gives information on the EBS design. This information is from Design Input Transmittal PA-SSR-99218.Tb.

#### **NUFT Input**

The parameters listed above are converted to NUFT input parameters Nitao (1998a, 1998b). Some of the parameters used in NUFT v 3.0s are not described in these reports, will be described in the NUFT v. 3.0s final report which will be available when v. 3.0s is qualified.

Because the UZ Site-Scale Model provides hydrologic data based on an active fracture dual permeability model and the EBS parameters were given based on continuum permeability measurements, we converted the EBS parameters to parameters that would be appropriate for an active fracture dual permeability model.

Table 1 Hydrostatigraphy (TBV)

Model Unit	Thickness (m)
	Ground surface
tcw11	0.
tcw12	83.086
tcw13	5.391
ptn21	4.893
ptn22	3.193
ptn23	2.754
ptn24	7.061
ptn25	15.410
ptn26	14.648
tsw31	1.992
tsw32	46.348
tsw33	87.382
tsw34	33.188
tsw35	107.370
tsw36	31.377
tsw37	15.674
tsw38	21.006
tsw39	2.871
ch1VI	0.
ch2VI	0.
ch3VI	0.
ch4VI	0.
ch5VI	0.
ch1Ze	14.004
ch2Ze	16.523
ch3Ze	16.523
ch4Ze	16.523
ch5Ze	16.553
ch6	18.867
pp4	9.932
pp3	30.732
pp2	16.846
pp1	29.619
bf3	0.
bf2	0.
	Water table

Table 2 Repository Location Relative to Hydrostratigraphy (TBV)

repository elevation (m)	1073.124
host rock unit	tsw35
distance from repository plane to top of water table (m)	343.131

Table 3 Ground Surface and Water Table Conditions (TBV)

Temperature at ground surface	16.544 °C
Pressure at ground surface	0.851e5 Pa
Air mass fraction at ground surface	0.986
Temperature at water table	32.39 °C
Pressure at water table	0.92e5 Pa

Table 4 Matrix Hydrologic Parameters for NBS

Model Layer	matrix parameters					
	permeability m <sup>2</sup>	porosity	Van Genuchten $\alpha$ 1/Pa	Van Genuchten m	residual saturation	satiated saturation
tcw11	3.86E-15	0.253	4.00E-05	0.47	0.07	1
tcw12	2.74E-19	0.082	1.81E-05	0.241	0.19	1
tcw13	9.23E-17	0.203	3.44E-06	0.398	0.31	1
ptn21	9.90E-13	0.387	1.01E-05	0.176	0.23	1
ptn22	2.65E-12	0.439	1.60E-04	0.326	0.16	1
ptn23	1.23E-13	0.254	5.58E-06	0.397	0.08	1
ptn24	7.86E-14	0.411	1.53E-04	0.225	0.14	1
ptn25	7.00E-14	0.499	5.27E-05	0.323	0.06	1
ptn26	2.21E-13	0.492	2.49E-04	0.285	0.05	1
tsw31	6.32E-17	0.053	3.61E-05	0.303	0.22	1
tsw32	5.83E-16	0.157	3.61E-05	0.333	0.07	1
tsw33	3.08E-17	0.154	2.13E-05	0.298	0.12	1
tsw34	4.07E-18	0.11	3.86E-06	0.291	0.19	1
tsw35	3.04E-17	0.131	6.44E-06	0.236	0.12	1
tsw36	5.71E-18	0.112	3.55E-06	0.38	0.18	1
tsw37	4.49E-18	0.094	5.33E-06	0.425	0.25	1
tsw38	4.53E-18	0.037	6.94E-06	0.324	0.44	1
tsw39	5.46E-17	0.173	2.29E-05	0.38	0.29	1
ch1z	1.96E-19	0.288	2.68E-07	0.316	0.33	1
ch1v	9.90E-13	0.273	1.43E-05	0.35	0.03	1
ch2v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch3v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch4v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch5v	9.27E-14	0.345	5.13E-05	0.299	0.07	1
ch2z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch3z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch4z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch5z	6.07E-18	0.331	3.47E-06	0.244	0.28	1
ch6	4.23E-19	0.266	3.38E-07	0.51	0.37	1
pp4	4.28E-18	0.325	1.51E-07	0.676	0.28	1
pp3	2.56E-14	0.303	2.60E-05	0.363	0.1	1
pp2	1.57E-16	0.263	2.67E-06	0.369	0.18	1
pp1	6.40E-17	0.28	1.14E-06	0.409	0.3	1
bf3	2.34E-14	0.115	4.48E-06	0.481	0.11	1
bf2	2.51E-17	0.259	1.54E-07	0.569	0.18	1

Table 5 Fracture Hydrologic Parameters for NBS

fracture parameters						
Model Layer	permeability m <sup>2</sup>	porosity	Van Genuchten $\alpha$ 1/Pa	Van Genuchten m	residual saturation	satiated saturation
tcw11	2.41E-12	2.80E-02	3.15E-03	0.627	0.01	1
tcw12	1.00E-10	2.00E-02	2.13E-03	0.613	0.01	1
tcw13	5.42E-12	1.50E-02	1.26E-03	0.607	0.01	1
ptn21	1.86E-12	1.10E-02	1.68E-03	0.58	0.01	1
ptn22	2.00E-11	1.20E-02	7.68E-04	0.58	0.01	1
ptn23	2.60E-13	2.50E-03	9.23E-04	0.61	0.01	1
ptn24	4.67E-13	1.20E-02	3.37E-03	0.623	0.01	1
ptn25	7.03E-13	6.20E-03	6.33E-04	0.644	0.01	1
ptn26	4.44E-13	3.60E-03	2.79E-04	0.552	0.01	1
tsw31	3.21E-11	5.50E-03	2.49E-04	0.566	0.01	1
tsw32	1.26E-12	9.50E-03	1.27E-03	0.608	0.01	1
tsw33	5.50E-13	6.60E-03	1.46E-03	0.608	0.01	1
tsw34	2.76E-13	1.00E-02	5.16E-04	0.608	0.01	1
tsw35	1.29E-12	1.10E-02	7.39E-04	0.611	0.01	1
tsw36	9.91E-13	1.50E-02	7.84E-04	0.61	0.01	1
tsw37	9.91E-13	1.50E-02	7.84E-04	0.61	0.01	1
tsw38	5.92E-13	1.20E-02	4.87E-04	0.612	0.01	1
tsw39	4.57E-13	4.60E-03	9.63E-04	0.634	0.01	1
ch1z	3.40E-13	1.70E-04	1.43E-03	0.631	0.01	1
ch1v	1.84E-12	6.90E-04	1.09E-03	0.624	0.01	1
ch2v	2.89E-13	8.90E-04	5.18E-04	0.628	0.01	1
ch3v	2.89E-13	8.90E-04	5.18E-04	0.628	0.01	1
ch4v	2.89E-13	8.90E-04	5.18E-04	0.628	0.01	1
ch5v	2.89E-13	8.90E-04	5.18E-04	0.628	0.01	1
ch2z	3.12E-14	4.30E-04	4.88E-04	0.598	0.01	1
ch3z	3.12E-14	4.30E-04	4.88E-04	0.598	0.01	1
ch4z	3.12E-14	4.30E-04	4.88E-04	0.598	0.01	1
ch5z	3.12E-14	4.30E-04	4.88E-04	0.598	0.01	1
ch6	1.67E-14	1.70E-04	7.49E-04	0.604	0.01	1
pp4	3.84E-14	4.30E-04	5.72E-04	0.627	0.01	1
pp3	7.60E-12	1.10E-03	8.73E-04	0.655	0.01	1
pp2	1.38E-13	1.10E-03	1.21E-03	0.606	0.01	1
pp1	1.12E-13	4.30E-04	5.33E-04	0.622	0.01	1
bf3	4.08E-13	1.10E-03	9.95E-04	0.624	0.01	1
bf2	1.30E-14	4.30E-04	5.42E-04	0.608	0.01	1

Table 6 Hydrologic Parameters for Fracture-Matrix Interaction for NBS

fracture parameters			
Model Layer	active fracture parameter	frequency 1/m	Fracture to matrix connection area $m^2/m^3$
tcw11	0.3	0.92	1.56
tcw12	0.3	1.91	13.39
tcw13	0.3	2.79	3.77
ptn21	0.09	0.67	1
ptn22	0.09	0.46	1.41
ptn23	0.09	0.57	1.75
ptn24	0.09	0.46	0.34
ptn25	0.09	0.52	1.09
ptn26	0.09	0.97	3.56
tsw31	0.06	2.17	3.86
tsw32	0.41	1.12	3.21
tsw33	0.41	0.81	4.44
tsw34	0.41	4.32	13.54
tsw35	0.41	3.16	9.68
tsw36	0.41	4.02	12.31
tsw37	0.41	4.02	12.31
tsw38	0.41	4.36	13.34
tsw39	0.41	0.96	2.95
ch1z	0.1	0.04	0.11
ch1v	0.13	0.1	0.3
ch2v	0.13	0.14	0.43
ch3v	0.13	0.14	0.43
ch4v	0.13	0.14	0.43
ch5v	0.13	0.14	0.43
ch2z	0.1	0.14	0.43
ch3z	0.1	0.14	0.43
ch4z	0.1	0.14	0.43
ch5z	0.1	0.14	0.43
ch6	0.1	0.04	0.11
pp4	0.1	0.14	0.43
pp3	0.46	0.2	0.61
pp2	0.46	0.2	0.61
pp1	0.1	0.14	0.43
bf3	0.46	0.2	0.61

Table 7 Thermal Parameters and Tortuosity Factor for NBS

Model Layer	rock grain density kg/m <sup>3</sup>	rock grain specific heat J/kg K	dry conductivity W/m K	wet conductivity W/m K	Tortuosity
tcw11	2550	823	1.60	2.00	0.7
tcw12	2510	851	1.24	1.81	0.7
tcw13	2470	857	0.54	0.98	0.7
ptn21	2380	1040	0.50	1.07	0.7
ptn22	2340	1080	0.35	0.50	0.7
ptn23	2400	849	0.44	0.97	0.7
ptn24	2370	1020	0.46	1.02	0.7
ptn25	2260	1330	0.35	0.82	0.7
ptn26	2370	1220	0.23	0.67	0.7
tsw31	2510	834	0.37	1.00	0.7
tsw32	2550	866	1.06	1.62	0.7
tsw33	2510	882	0.79	1.68	0.7
tsw34	2530	948	1.56	2.33	0.7
tsw35	2540	900	1.20	2.02	0.7
tsw36	2560	865	1.42	1.84	0.7
tsw37	2560	865	1.42	1.84	0.7
tsw38	2360	984	1.69	2.08	0.7
tsw39	2360	984	1.69	2.08	0.7
ch1z	2310	1060	0.70	1.31	0.7
ch1v	2310	1060	0.70	1.31	0.7
ch2v	2240	1200	0.58	1.17	0.7
ch3v	2240	1200	0.58	1.17	0.7
ch4v	2240	1200	0.58	1.17	0.7
ch5v	2240	1200	0.58	1.17	0.7
ch2z	2350	1150	0.61	1.20	0.7
ch3z	2350	1150	0.61	1.20	0.7
ch4z	2350	1150	0.61	1.20	0.7
ch5z	2350	1150	0.61	1.20	0.7
ch6	2440	1170	0.73	1.35	0.7
pp4	2410	577	0.62	1.21	0.7
pp3	2580	841	0.66	1.26	0.7
pp2	2580	841	0.66	1.26	0.7
pp1	2470	635	0.72	1.33	0.7
bf3	2570	763	1.41	1.83	0.7
bf2	2410	633	0.74	1.36	0.7

Table 8 Infiltration Rates (TBV)

Current Climate	Monsoon	Glacial
10.14 mm/yr	24.09 mm/yr	38.66 mm/yr

Table 9 Hydrologic Properties for EBS

Material	permeability $m^2$	porosity	Van Genuchten $\alpha$ 1/Pa	Van Genuchten n	residual saturation	satiated saturation
backfill	$1.43 \times 10^{-11}$	0.41	$2.7523 \times 10^{-4}$	2.0	0.024	1
invert	$6.152 \times 10^{-10}$	0.545	$1.2232 \times 10^{-3}$	2.7	0.092	1

Table 10 Thermal properties for EBS

Material	rock grain density $kg/m^3$	rock grain specific heat $J/kg\ K$	dry conductivity $W/m\ K$	wet conductivity $W/m\ K$	Tortuosity
backfill	2700	795.492	0.33	0.33	0.7
invert	2530	948	0.66	0.66	0.7

Table 11 EBS Geometry

	Value	Source
Drift diameter	5.5 m	PA-SSR-99218.Tb
Waste package outer diameter	1.67 m	Calculated using PA-WP-99184.T
Location of waste package center above bottom of drift	1.945 m	PA-SSR-99218.Tb
Location of waste package center below the springline	0.805 m	PA-SSR-99218.Tb
Angle of Repose	26°	PA-SSR-99218.Tb
Minimum depth of backfill cover (this occurs at an angle equivalent to the angle of repose measured off the vertical drawn from the waste package centerline)	1.495 m	PA-SSR-99218.Tb
Drip shield thickness	0.02 m	B00000000-01717-0210-00074 Rev00 (same as SSR-WP-99242.T)
Air gap between waste package surface and the inside of drip shield	0.396 m	Calculated using PA-SSR-99218.Tb and waste package outer diameter above
Location of backfill spoil peak (this is the location where the top of the backfill intersects the vertical drawn from the drift centerline) above the drift springline	2.25 m	PA-SSR-99218.Tb
Backfill/drift wall intersection point	1.0 m above the springline at the drift wall intersection	PA-SSR-99218.Tb
Air gap above invert and below waste package surface	0.504 m	Calculated using PA-SSR-99218.Tb and waste package outer diameter above
Inside radius of drip shield	1.231 m	PA-SSR-99218.Tb
Top of invert as measured from bottom of drift	0.606 m	PA-SSR-99218.Tb
Waste package spacing	0.1	PA-WP-99184.T
Emplacement drift spacing	81 m	PA-SSR-99218.Tb

## **CRITERIA**

The model developed in this report is based on a flow through porous media model (unsaturated, nonisothermal), using a dual permeability approach (DKM) with active fractures concept (AFC). This conceptual is consistent with the model approach used in most recent UZ Site-Scale Model. All the simulations presented in this section were performed using the USNT module of NUFT 3.0s. NUFT has been used extensively to simulate thermal-hydrological behavior on the Yucca Mountain Project. For example, NUFT, using the dual permeability approach, but not with the active fracture concept, was the basis for simulating WP environment conditions for the most recent total system performance assessment–viability assessment (OCRWM 1998, Volume 3, Section 3.2. Comparison of models based on this approach against data from the Drift Scale Test are being performed as part of the Thermal Testing AMR. There are no currently available appropriate field or laboratory tests to compare with the drainage calculations presented here, but to the extent that testing is conducted in the future, this model can be compared with those data.

## **CODES AND STANDARDS**

The model/analysis documented in this report were developed using the applicable QA procedures, and conventional engineering/scientific standards.

## ASSUMPTIONS

1. Nonisothermal, unsaturated flow through porous media, using an implicit dual permeability (DKM) with active fracture concept (AFC) as represented by the USNT module of the NUFT 3.0s computer code applies.
2. The UZ Site-Scale Model is representative of the unsaturated hydrology (e.g., hydrologic parameters and unit definition) of the site.
3. A 2-D, steady-state analysis is conservative.
4. The location modeled, approximately in the center of the repository, is representative of the site.
5. If large amounts of water are entering the EBS, then the temperatures in the EBS are below boiling and to first order, the heat given off by waste packages can be neglected for assessing drainage.
6. The key effect of THC/THM or construction processes as they apply to water drainage is to assume that fracture permeability below the drift is significantly decreased.

## ANALYSIS/MODEL

### Methodology

*General* – An effort was made to be as consistent as possible with that of other AMRs being prepared for the EBS and NFE PMRs, and the YMP UZ Site-Scale Model.

*Conceptual Model* – The system is described as steady-state flow through porous media model, using a dual permeability with active fractures approach. Infiltration is applied to the top of the model domain, which represents the ground surface. The region between the top of the drift and the backfill is represented by the host-rock unit so that infiltration applied to the top of the model enters the drift. This is equivalent to applying seepage directly on the top of the backfill, but it preserves the model domain for easier comparison with simulations being performed for other AMRs.

*Numerical Model* - All the simulations presented in this section were performed using the USNT module of NUFT 3.0s.

*Model Domain* - The 2D model domain extends vertically from the ground surface to the water table and contains the model units described in Table 1, and horizontally from the center of a drift to the center of the pillar between the drifts. The grid is rectangular with irregular spacing and contains 1200 cells. The current “chimney” domain model was chosen for consistency with other past and concurrent NUFT EBS modeling efforts and because the boundary conditions are better defined. A close-up of the EBS region of the modeling domain is shown in Figure 1. At the left hand side of this model domain, which represents the center of the EBS, invert is represented by 2 cells.

*Hydrologic properties* – An active fracture, dual permeability approach was used to represent hydrologic properties. See Tables 4-7. When these values are changed to examine parameter sensitivity, this is explicitly stated. Since the key to drainage is the permeability of the host rock unit below the EBS, we investigate the consequence of changes to the permeability of this rock, in several simulations. Such permeability changes occur due THC/THM or construction processes. In these simulations, the permeability of the fractures in host rock unit directly (1 cell) below the invert was reduced by many orders of magnitude, to the permeability of the host rock matrix. In other cases, the fracture permeability in the host rock directly (1 cell) below the entire EBS was reduced to this value. These permeability reductions will be referred to as “fractures plugged below invert” and “fractures plugged below EBS”, respectively. The region immediately above the invert is represented in this model by impermeable material, so ponding of water above the invert can not occur (i.e., water is diverted horizontally).

*Boundary Conditions* – Boundary conditions for temperature, pressure and relative humidity must be defined. The temperature and pressure parameter values for ground surface and water table listed in Table 3 are held constant. The liquid saturations at the ground surface and water table are held to 0 and 1, respectively, and the air at the ground surface is assumed to have 100%

relative humidity. Side boundaries are assumed to be reflective, that is, there is no flow of water, air or heat through the side boundaries.

*Infiltration* – A constant infiltration is applied to the ground surface. For some simulations, we assumed that infiltration was equal to the current climate or glacial infiltration rate (see Table 3). In other simulations, we calculated the infiltration assuming that the infiltration is concentrated spatially such that the entire flux between adjacent pillar centerlines is focused into the intervening drift (i.e., multiply infiltration rate by  $40.5/2.75$ ), and then applied that rate across the entire model domain. These rates will be referred as focused infiltration rates. The greatest infiltration rate considered is the focused glacial rate ( $38.66 \text{ mm/yr} \times 40.5/2.75 = 570 \text{ mm/yr}$ ).

*Performance Goals* – The EBS is considered to fail with respect to its ability to drain incoming water when the saturation averaged over the bottom half of the invert at the point furthest from the center of the drift reaches a value of 1. In the numerical model, this location is represented by a 0.303 m long by 0.35 m wide cell. Of the six cells used to represent the invert in the numerical model, this cell was always the most saturated one.

*Simulations* - A description of the simulations run for this AMR and results of these simulations are given in Table 12. Results are reported in terms of liquid saturation for the cell corresponding to Cell #1 marked in Fig. 1. Results are also reported for the cell directly above this cell, marked as Cell #2 in Fig. 1. Due to the TBV status of the NUFT 3.0s code and much of the data used as model input, these results are marked TBV.

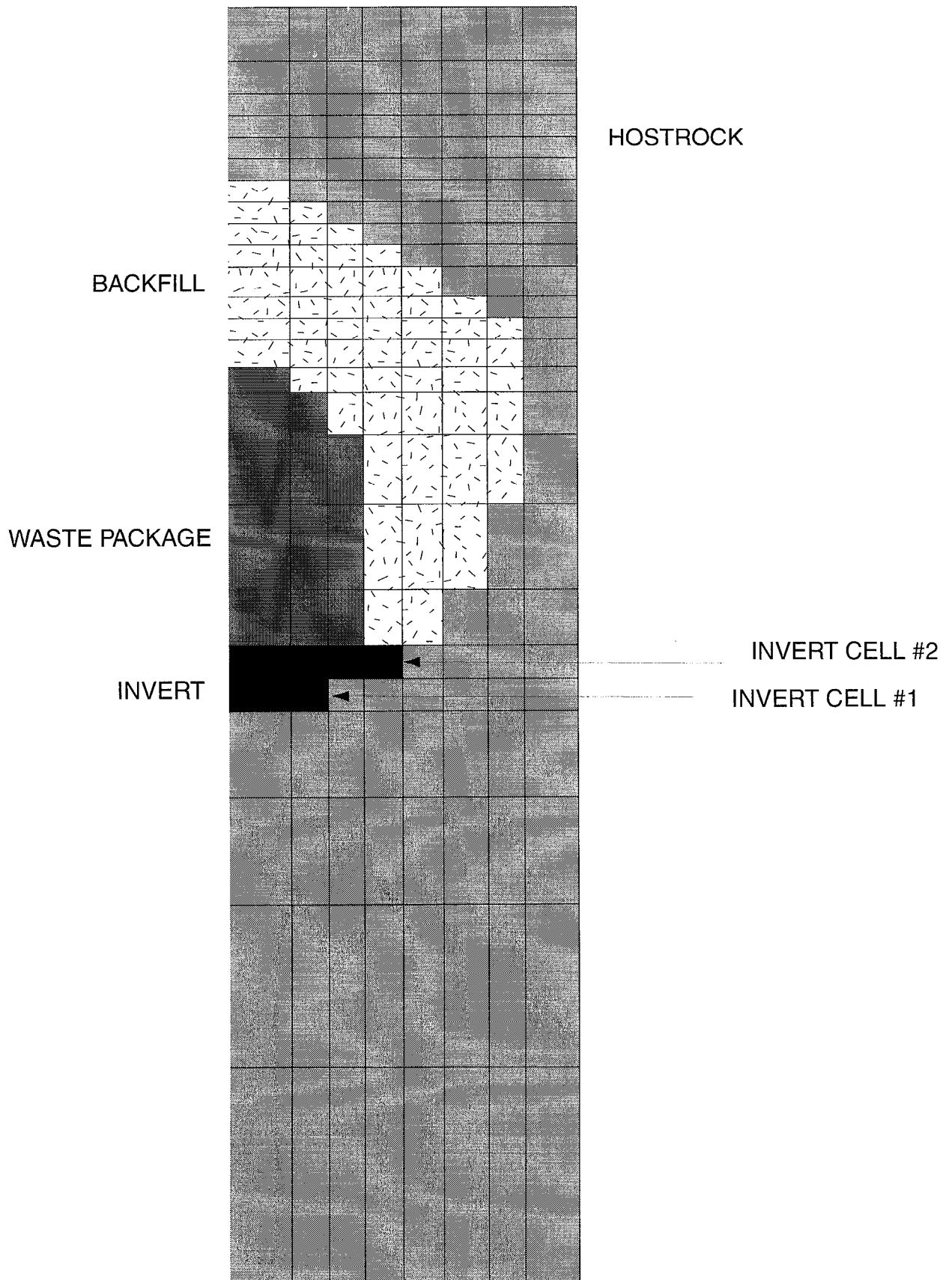


Fig. 1. Close-up of EBS region of model grid

Table 12 Drainage Simulations: Description and Results (TBV)

	Infiltration Rate		Changes to EBS properties	Changes to NBS properties	Saturation Cell #1 (see Fig. 1) at steady-state*	Saturation Cell #2 (see Fig. 1) at steady-state*
A	Glacial	38.66 mm/yr			0.189	0.140
B	Focused Glacial	570 mm/yr			0.317	0.200
C	Focused Glacial	570 mm/yr	Decrease backfill permeability by 10x		0.299	0.176
D	Focused Glacial	570 mm/yr	Decrease invert permeability by 10x		0.317	0.20
E	Focused Glacial	570 mm/yr	Decrease invert and backfill permeability by 10x		0.299	0.176
F	Glacial	38.66 mm/yr		fractures plugged below invert	0.756	0.163
G	2xGlacial	77 mm/yr		fractures plugged below invert	0.998	0.188
H	3xGlacial	116 mm/yr		fractures plugged below invert	1.000	0.212
I	Current Climate	10.14 mm/yr		fractures plugged below EBS	0.984	0.180
J	Monsoon	24.09 mm/yr		fractures plugged below EBS	1.000	0.971

\* rounded to 3<sup>rd</sup> decimal place

## CONCLUSIONS

The EBS successfully drains water entering the EBS for even extreme infiltration rates unless fractures below the EBS become clogged and the permeability of those fractures reduced to matrix permeability values, as might be the result of THC/THM processes or repository construction activities. Drainage performance is impeded if fractures are clogged below the invert but not below the entire EBS, but the EBS can still drain water at significant infiltration rates. Drainage performance is seriously impeded if fractures are clogged below the entire EBS. The EBS is considered to fail with respect to its ability to drain incoming water when the saturation averaged over the bottom half of the invert at the center of the drift reaches a value of 1.

For a "focused glacial" infiltration rate, the EBS successfully drains water entering the EBS. The saturation averaged over the bottom half of the invert never exceeds 0.32 for this infiltration rate, even if the permeability of the backfill and/or the invert is reduced by a factor of 10x. A "focused glacial" infiltration rate is defined as follows: assume a glacial infiltration rate is concentrated spatially such that the entire flux between adjacent pillar centerlines is focused into the intervening drift, and then apply that rate across the entire model domain.

If fractures below the invert become clogged, the EBS fails to drain at an infiltration rate of 3x the glacial rate. If fractures below the entire EBS become clogged, the EBS fails to drain at an infiltration rate equal to the monsoon infiltration rate.

This water drainage model is based on unsaturated flow through porous media, using an implicit dual permeability (DKM) with active fracture concept (AFC) as represented by the USNT module of the NUFT 3.0s computer code. An effort was made to make this approach as consistent as possible with the approach being used by other AMRs being performed for the EBS PMR and the YMP UZ Site-Scale model. This model is a 2D, steady-state model representative of the center of the repository with waste package heat neglected. The region between the host rock and the backfill is treated as host rock and the region between the invert and the backfill is represented by an impermeable material.

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